Estimates of Sampling Bias using Subsampled Airs Data

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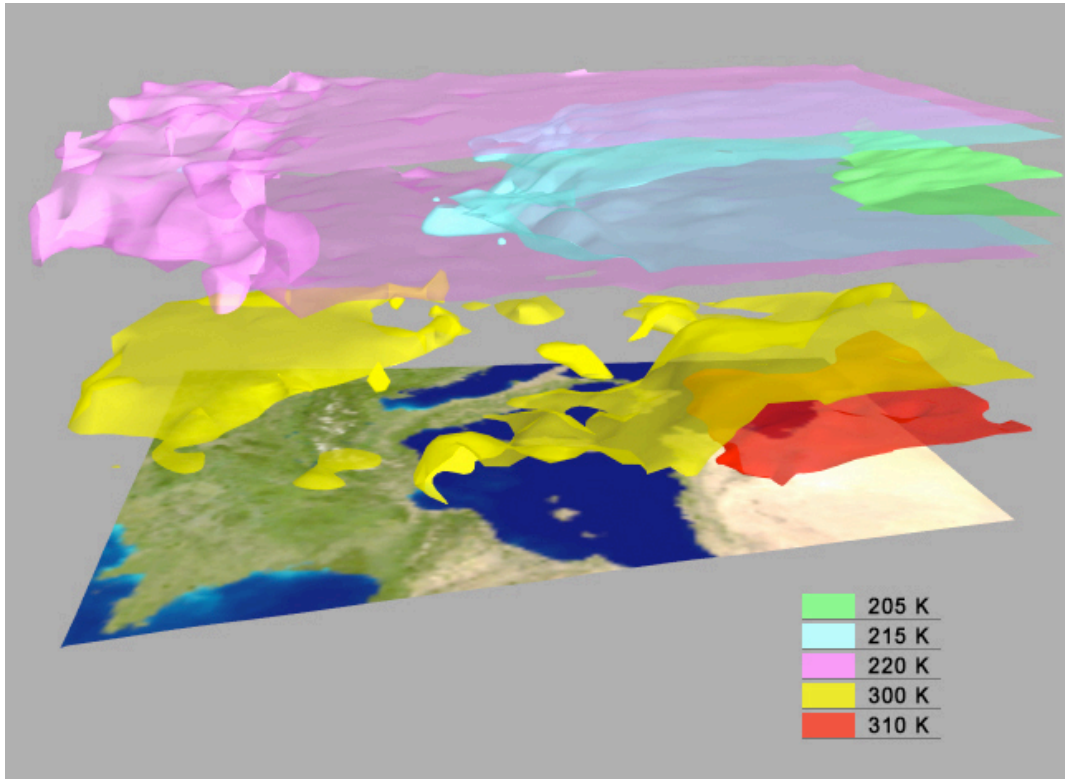
What Do We Sample?



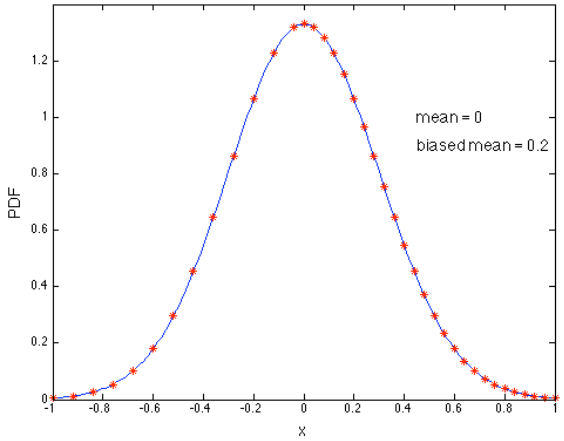
Airs temperature reconstruction

Climate variables are random functions of space and time.

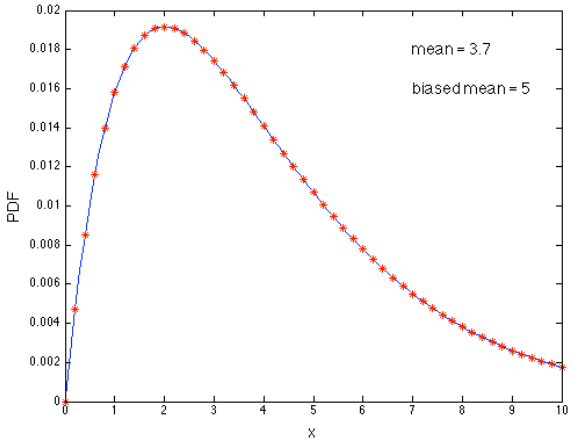
Their parent PDFs are unknown or poorly known.

Undersampling of a parent PDF can lead to a biased mean, i.e. affect SI traceable accuracy.

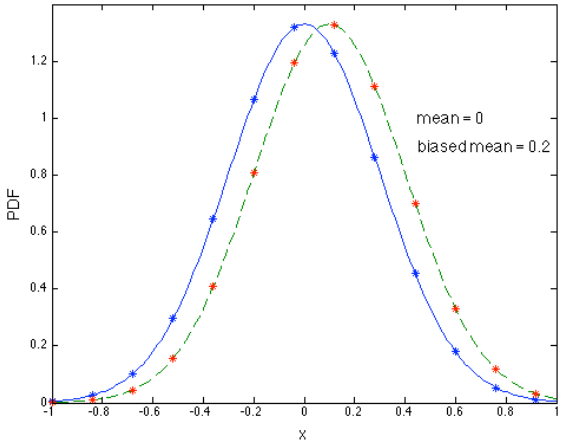
General Causes of Sampling Biases



(up) Symmetric parent PDF unevenly sampled.



(mid) Non-symmetric parent PDF sampled evenly.



(low) Non-stationary parent PDF sampled evenly.

Sampling Bias Estimates

Let

$$\langle x \rangle = (x_1 + x_2 + \ldots + x_n) / n,$$

$$s_n = \left(\sum_1^n (x_i - \langle x \rangle)^2 / (n-1) \right)^{1/2}$$

where $(x_1, x_2, \ldots, x_n)$ is a sample of measured values.

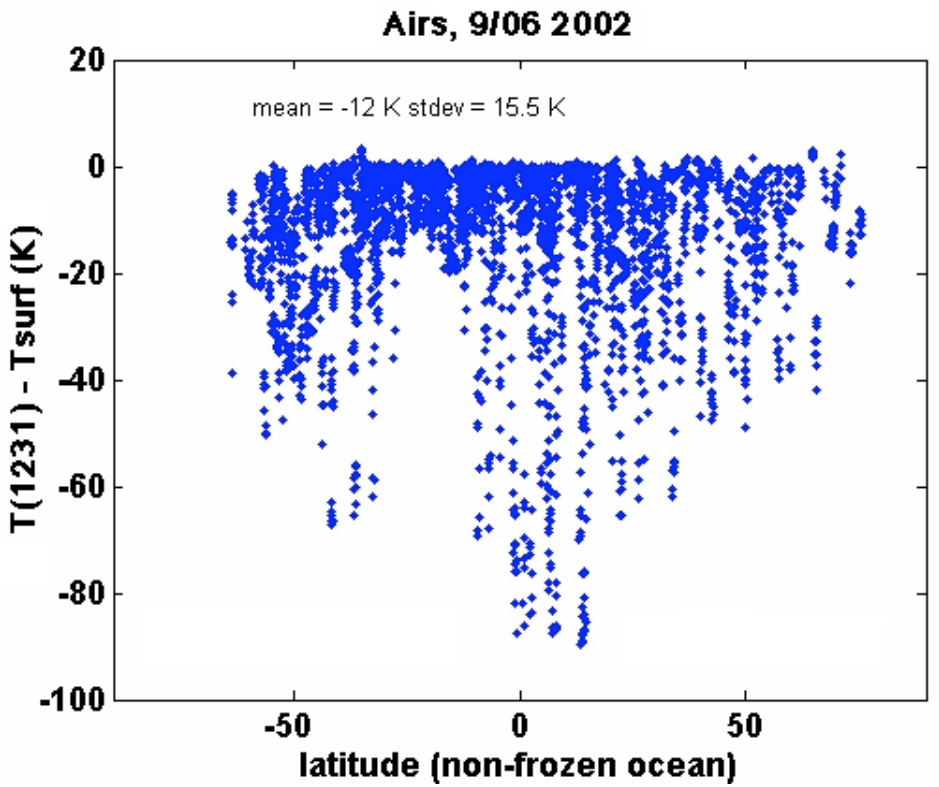
If x_i are independent normal, then $\langle x \rangle$ is measured with accuracy

$$\langle x \rangle = \langle x \rangle_{true} \pm t_n s_n n^{-1/2},$$

t_n are numbers from t-distribution: for 3σ confidence $t_n \to 2.807$ as $n \to \infty$.

If x_i are not independent: $n^{-1/2} \to n^{-(1-H)}$ ($0<H<1$ is Hurst exponent), i.e. larger n is needed!

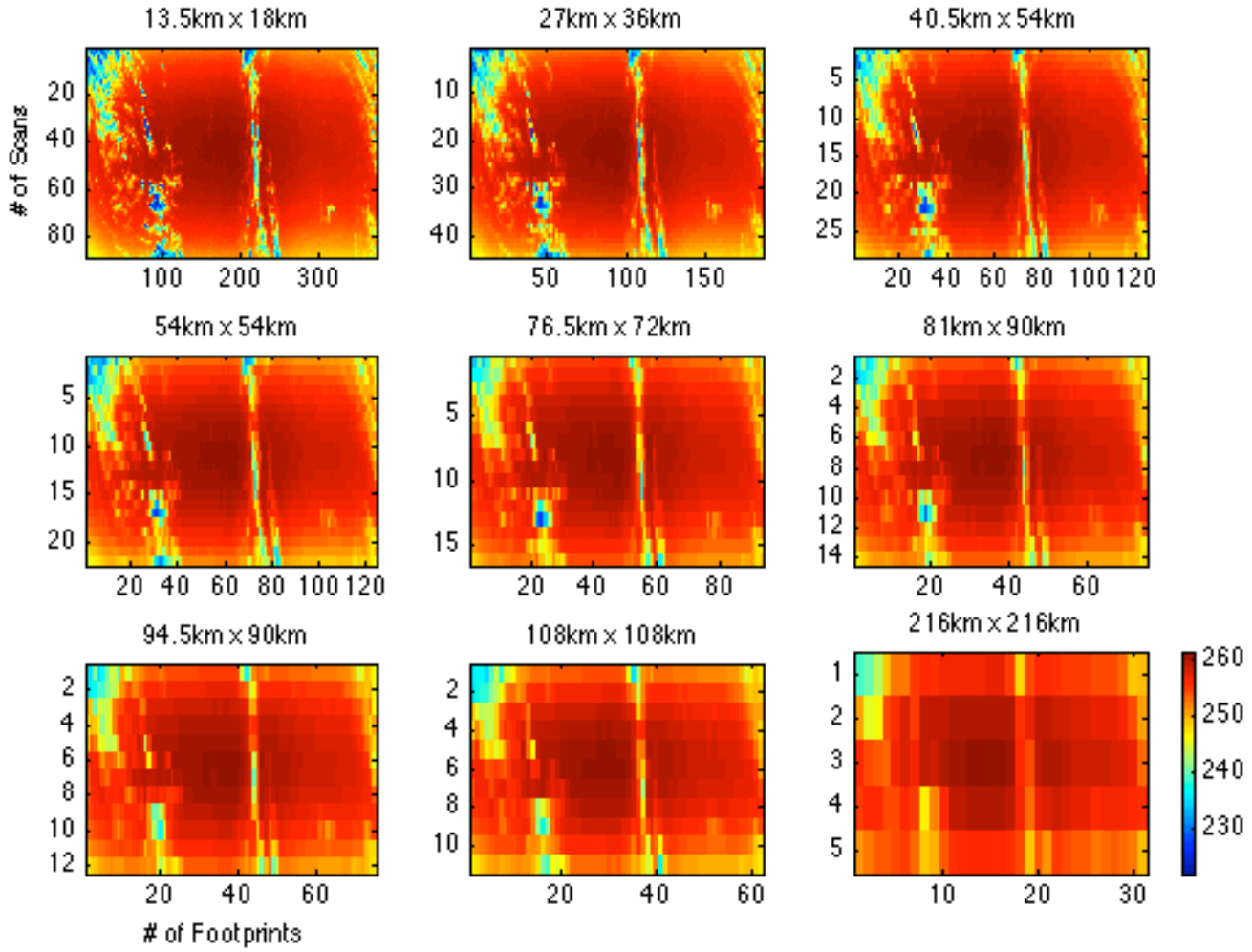
A Natural Cause of Sampling Biases



The accuracy of sampling is limited by scene variability due to clouds (cold excursions in fig) through most of the infrared spectrum.

The highest variability is in the window channels. The variability for 2388 cm^{-1} 400mb channel is a factor of two lower than for 1231 cm^{-1} surface channel.

An Example of Spatial Sampling

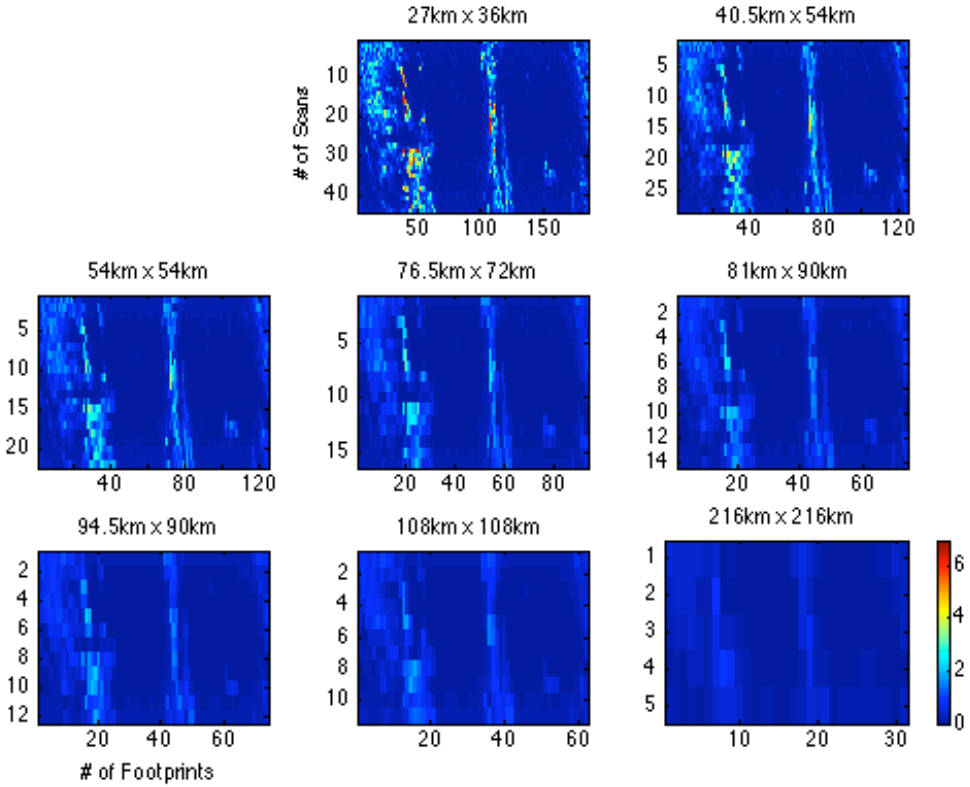


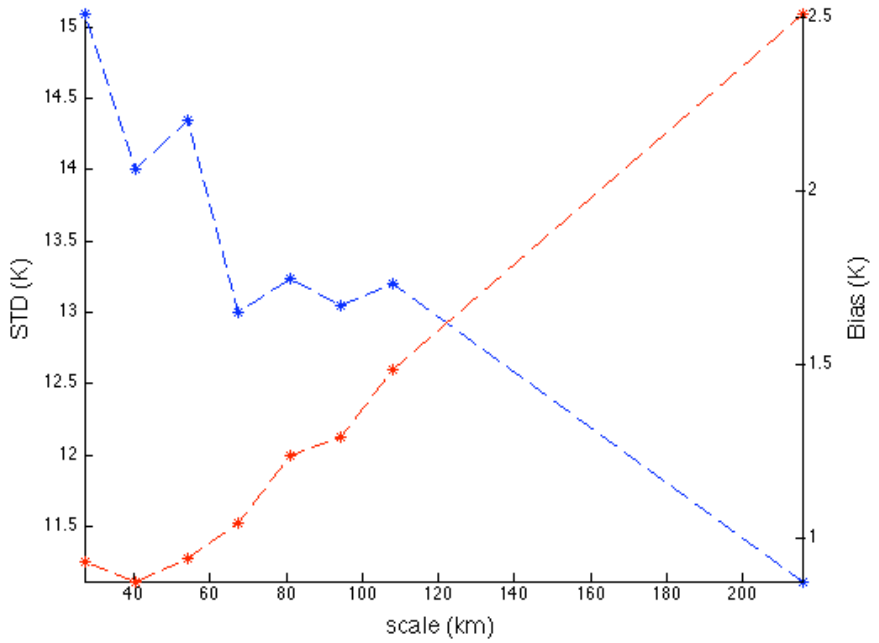
A scene as viewed by instruments with different FOVs.

Airs Radiances (TB, at 4.3μm), May 1, 2008, 30S–30N over ocean.

n	=	4	9	12	23	30	35	48	192	-- number of averaged pixels
tn	=	5.60	3.69	3.43	3.10	3.03	2.97	2.94	2.81	-- 3σ ss level from t-distribution

Bias Estimates

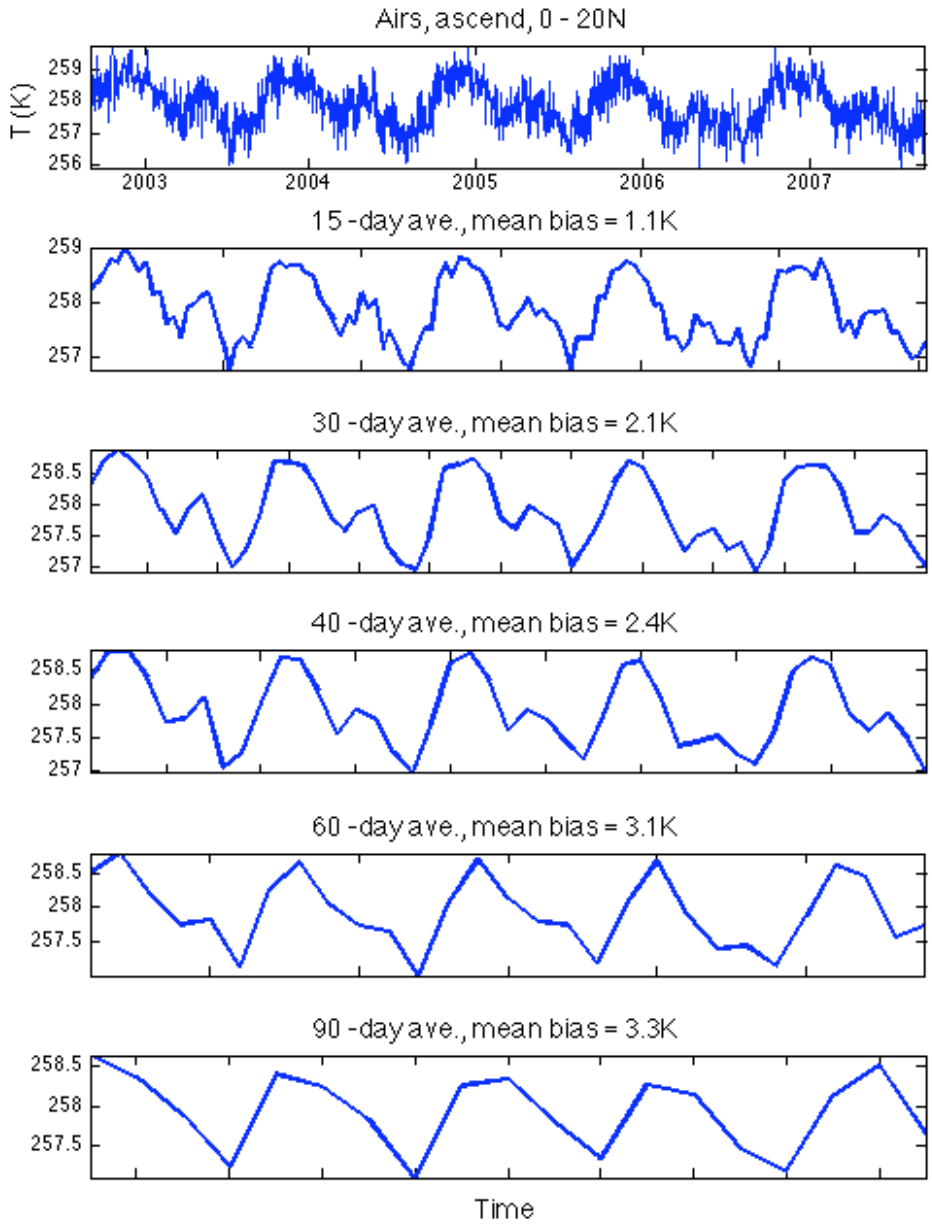




Distributions of $s_n n^{-1/2}$ are wide.

Averaged bias weakly depends on scale in 10-100 km range.

An Example of Temporal Sampling

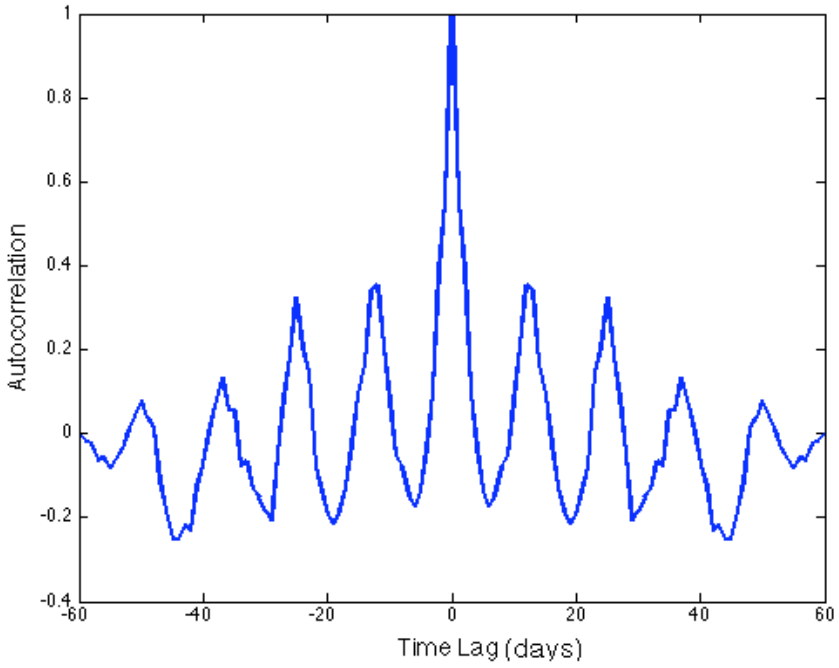


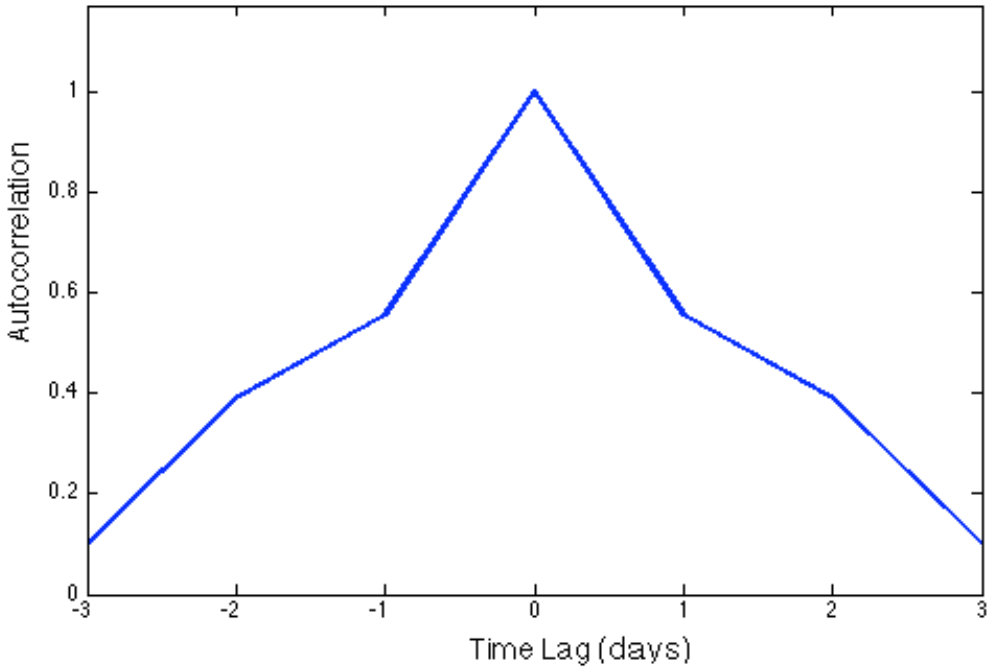
Airs Daily Radiances
(TB at 4.3μm), 2002-2007,
0–20N zonally averaged.

Bias estimates (bars) for 15 to
90-day means of Airs data.

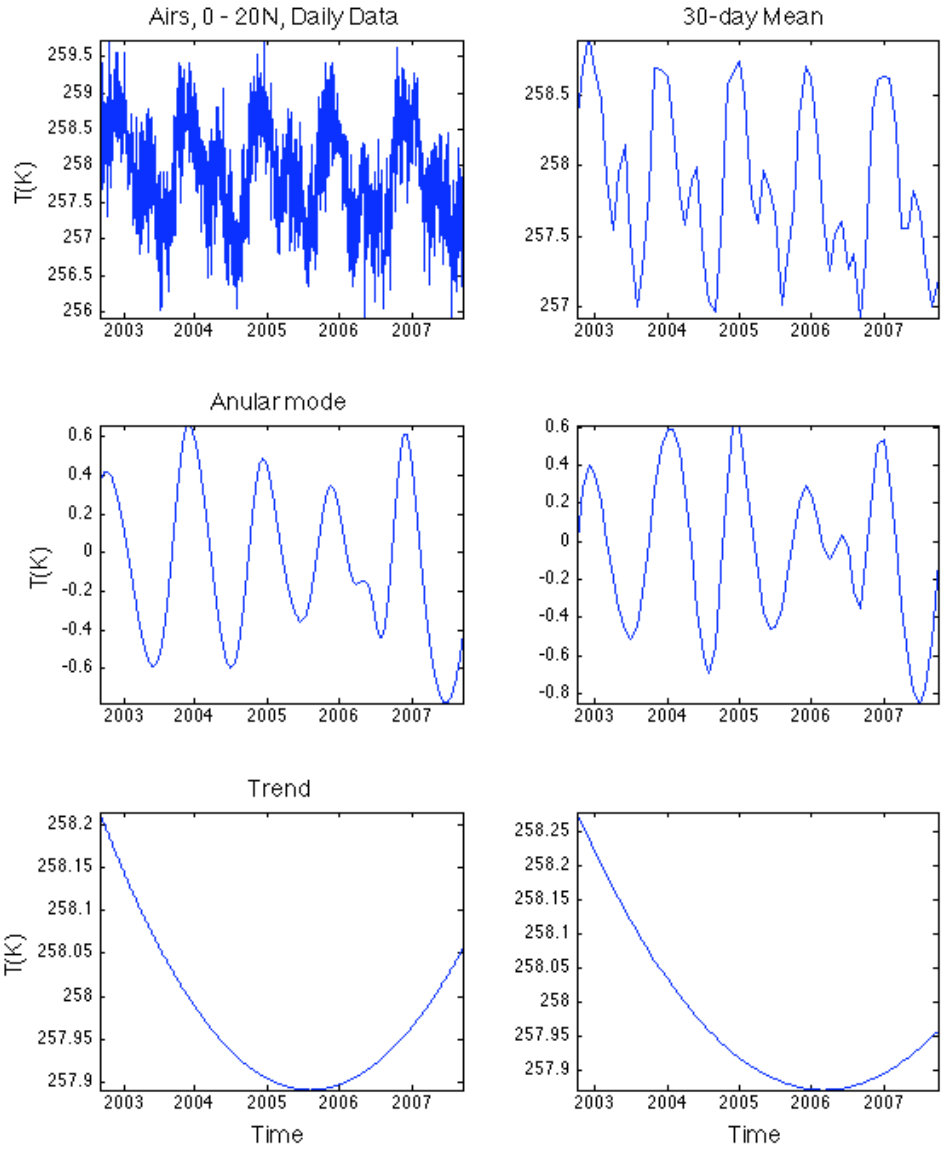
Mean bias weakly depends on time scale

Temporal Memory of (data – 30d ave) Record





Effect of Temporal Sampling on Annular Modes and Trend (EMD Filter)



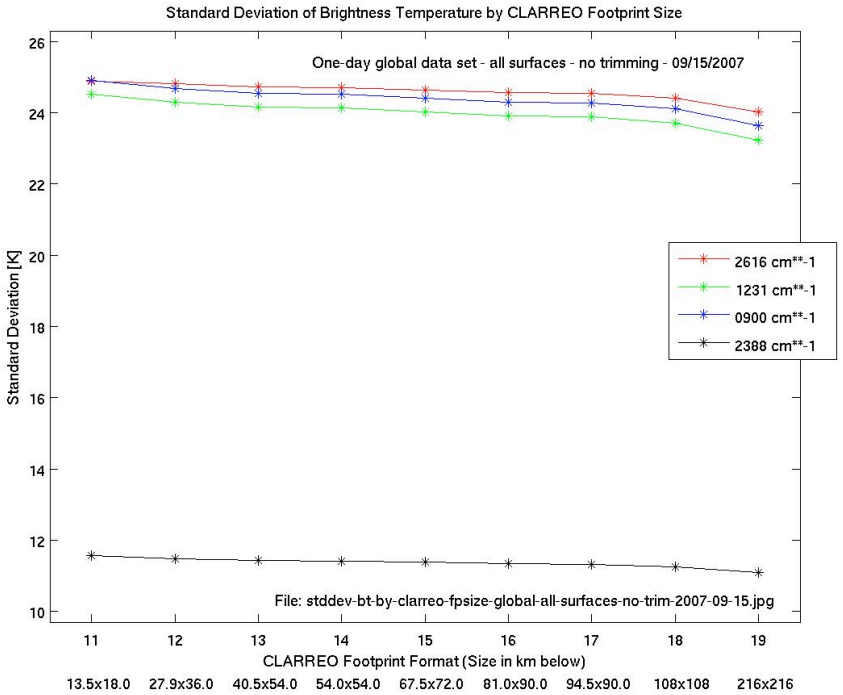
Daily and 30d averages

Annual modes (non-stationary!).

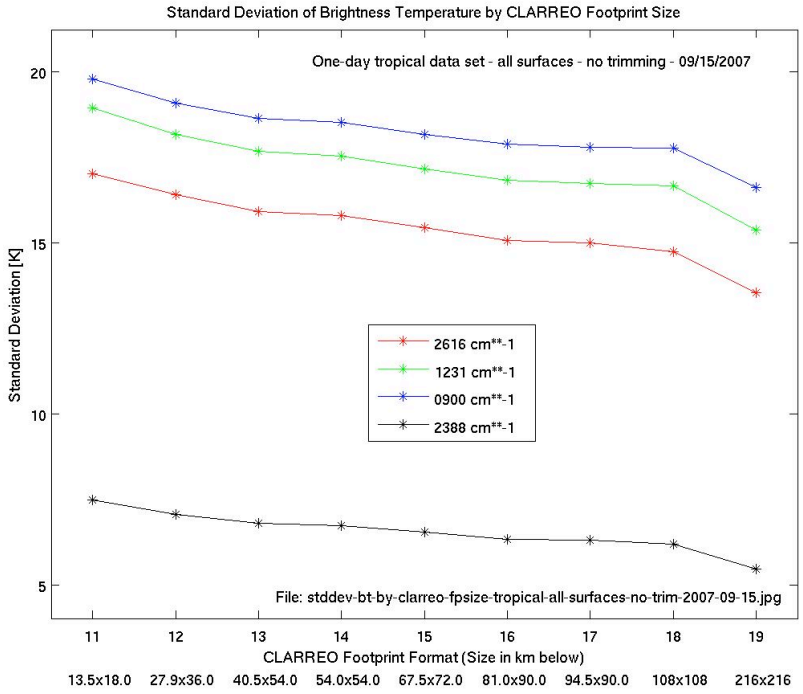
Residuals (trends). The trend for 30-day mean is not statistically significant.

High Scene Horizontal "Noise" Varies Slowly with Spatial Resolution

Global



Tropical



Go Global

Spacecraft (6.76 km/s) in a polar orbit taking one spectrum every 14.8 sec (FOV =100km) records

$$n_1 = 24\text{hrs}/14.8\text{sec} = 5{,}840$$

samples from the parent population. For 3 spacecraft with 2 instruments each

$$n_6 = 35{,}044.$$

$$\text{Global Daily Bias (T)} = t_n \, s_n \, n^{-1/2}$$

$$= 2.807 \times 24 \times (5840)^{-1/2} = 0.88\text{K}, \quad n = n_1$$

$$= 0.36\text{K}, \quad n = n_6$$

Go Zonal

Split the globe into N_z zones: n ➔ n/N_z, lower s_n = 12 K (for a tropical zone population). Day-Night split adds a factor of 2.

One-day radiometric accuracy of spectra (due to scene variability alone) is now

$$\text{Zonal Daily Bias (T)} = 0.44\, N_z^{1/2}\, K, \quad n = n_1$$
$$= 0.18\, N_z^{1/2}\, K, \quad n = n_6.$$

Sample D days to get 0.1K accuracy

$$0.1K = 0.44\,(0.18)\, N_z^{1/2}\, D^{-1/2} \quad \rightarrow \quad D = 19\, N_z, \quad n = n_1$$
$$= 3\, N_z, \quad n = n_6$$

For N_z = 12, D = 228 days (n = n_1), D = 36 days (n = n_6).

For FOV = 20 km with a 10 footprint swath: n ➔ 50n,
D = 4 days (n = n_1), D = 1 day (n = n_6).

Conclusions

- Sampling places serious limits on SI Traceable accuracy (bias)
- Bias due to natural variability weakly depends on scale in the range (10-100 km)
- Reaching 0.1K radiometric accuracy due to natural scene variability with a 100 km FOV in a polar, nadir scanning orbit requires the CLARREO spectra have to be averaged over too long (annular) time scale compromising the detection of trends
- Decreasing FOV to 20 km and using a 10 footprint wide swath provides a factor 50 increase in the number of samples allowing to reach the 0.1K accuracy using daily data averaged over 12 zones
- Estimates may be worsen when correlations between samples included